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Influence of fortified *in situ* rice residue compost and zinc nano fertilizer on growth and yield of rice (*Oryza sativa* L.) under rice cultivation methods

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ABSTRACT

This study was conducted during the kharif, 2020 at ICAR-Perunthalaivar Kamaraj Krishi Vigyan Kendra, Puducherry, India aimed to examine the effect of fortified in situ rice residue compost, zinc nano fertilizer on the growth and yield of rice under rice cultivation methods. The experiment was conducted in a split plot design; 3mainplots (TPR, DSR and AR) and eight subplots (fortified manures and nano zinc particles) with three replications. The results revealed that the TPRsignificantly improved tillers, LAI, productive tillers, panicle weight, grain and straw yield, zinc content and uptake and it was statistically on par with DSRand superior over AR. Nutrient management, fortified manure + ZnO NPs (SP+FS) significantly registered higher growth and yield attributes, Zn content and uptake of rice over to ZnO seed priming alone, $ZnSO_4$ and control. The PGPM, humic acid and seaweed extract fortified organic manures either FYM or rice residue compost, nano zinc as seed priming and foliar spray under TPR or DSR have the potential to maximize rice production without foregoing soil sustainability.

Keywords: Rice, fortified rice residue compost, nano zinc, cultivation methods, yield

INTRODUCTION

Rice (*Oryza sativa* L.) is the major staple crop and a mainstay for the rural population and their food security. India is the second-largest producer of rice. Transplanting rice (TPR) is the traditional system of rice crop establishment and pronounces to be most dominant in irrigated low land. TPR accounts for 21 per cent of operational cost and critically it takes energy of 30 persons per hectare per day. Due to scarcity of water and labour, the area under transplanted rice in world is declining. Depleted soil productivity and reduced groundwater level are the main challenges in present-day rice cultivation. It is known that 4000 litres of water are used to produce 1 kg of rice in many areas and even more water usage in states of Punjab, Haryana, Puducherry (Sharma *et al.,* 2018). Water availability for agriculture and for rice cultivation, in particular, will be less in the future and hence, we need to explore a new range of water-saving technology for rice production. Direct-seeded rice (DSR) has emerged as a feasible alternative establishment method and reduces labour requirement of 34%, shortens the crop duration by 7-10 days, cost of cultivation saving of 29 % and can produce as much grain yield as that of the transplanted crop and similarly, aerobic rice cultivation (AR) is another less water and labour demanding technique in comparison to TPR. Dry seeding uses 15.3% less water and increased nitrogen use efficiency than TPR. Straw is the only organic material available in significant quantities to most rice farmers, around 40 % of N, 30-35 % of P, 80% of K, and 40 to 50% of S nutrient assimilated by rice crop remains in vegetative plant parts at crop maturity. On the other hand, rice straw composting is the best alternative to manage this resource, besidesits use for restoration of soil health. Straw contains various macro and micronutrients, which make a payment to the nutrient budgeting of farms if returned to the soil. The recent studies have indicated the combined application of biofertilizers & bioagents along with rice straw @2.5-7.5 t ha^{-1}restored the soil health and promoted the induced rice systemic resistance for increasing the rice productivity to the tune of 7.1 to 7.9-10.1 tha^{-1} (Simarmata*et al.*, 2016).

In India, Zn deficiency is reported to occur to the extent of 60% of the cultivable area that coincided with the reduction in crop yield and quality to the tune of 25-35%. Nano fertilizers are useful over conventional fertilizers as they increase soil fertility, yield and quality parameters of the crop. They are non-toxic and less harmful to the environment and humans. Jangid *et al.* (2019) concluded that RDF + foliar

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sprays of nano ZnO at 1000 ppm or 1500 ppm had recorded significantly higher grain and straw yield. Keerthana (2020) reported that application ZnO NPs through seed priming and foliar spray increased the growth and yield of rice besides improving the zinc content and uptake. The present study aimed with the objective to maximizing rice yield under various rice production systems through *in situ* decomposition of PGPM consortia and bioactive stimulants fortified rice residue and nano zinc application.

MATERIAL AND METHODS

The experiment was conducted at research farm of ICAR-Perunthalaivar Kamaraj Krishi Vigyan Kendra (PKKVK), Puducherry, Indiaduring the *kharif,* 2020. The site is located at 7.8 km away from the Bay of Bengal, geo-positioned between 11° 93' North latitude and 79° 77' East longitude and 15 meters above MSL. The initial soil properties of the experiment site noted a pH 7.10, EC 0.19 dS m^{-1}, available soil nutrient status indicated low organic carbon (2.4 g kg^{-1}), low N (141 kg ha^{-1}), high P_2O_5 (49 kg ha^{-1}) medium K_2O (168 kg ha^{-1}) and DTPA-Zn (1.02 mg kg^{-1}).The experiment was laid out in the split plot design with 3 main plots treatments, M_1 - Transplanted Rice (TPR), M_2 - Direct Sown under puddled condition (DSR), M_3 - Aerobic Rice (AR) – Direct seed sown under unpuddled condition and 8 Sub Plots T_1 - 100% RDF (control), T_2 - T_1 + $ZnSO_4$ @ 25 kg ha^{-1}, T_3 - 75% RDF+ (PGPM consortia + BA compounds) fortified FYM @ 5t ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}, T_4 - 75% RDF+ *In situ* rice residue compost fortified (PGPM consortia + BA compounds) + $ZnSO_4$ @ 25 kg ha^{-1}, T_5 - 75% RDF+ fortified FYM @ 5t ha^{-1} + ZnO NPs seed priming, T_6 - 75% RDF+ fortified *Insitu* rice residue compost + ZnO NPs seed priming, T_7 - T_5 +ZnO NPs (foliar spray), andT_8 - T_6 + ZnO NPs (foliar spray). The PGPM cultures *viz.,* Azospirillum, Phosphobacteria, potash solubilizing bacteria, zinc solubilizing bacteria, *Pseudomonas fluorescence* and *Trichoderma sp.* cultures were mixed in equal quantities to make consortia and fortified with FYM @ 2.8 kg t^{-1}. Bio Active compounds (BA) *viz.,* humic acid and seaweed extract were also fortified with FYM @ 100 mL t^{-1}. The*insitu* incorporation of riceresidueswas carried out@ 7.5 t ha^{-1} at 20 days beforesowing / transplanting to ensure desirable decomposition and N deficiency due to immobilization. For *in situ*rice residue fortification treatments PGPM consortia @ 14 kg ha^{-1} and BA compounds @ 500 Ml ha^{-1} were sprinkled uniformly overriceresidues and incorporatedinto the soil. Irrigations at regular intervals were done to maintain adequate moisture for the decomposition of rice residues. The nutrient content of paddy residue and FYM are presented in Table 1.

Table 1: Nutrient content of rice residue and FYM

Organic manure	pH	EC dSm^{-1}	OC%	N (%)	P (%)	K (%)	Zn (mg kg^{-1})	Fe (mg kg^{-1})
Rice residue	7.28	3.42	34.7	0.47	0.22	1.08	30.4	115
FYM	7.04	2.28	16.5	0.51	0.24	0.49	68.8	162

Zinc sulphate was applied @ 25 kg ha^{-1} as soil application (SA), for nano zinc seed priming (SP) treatments, rice seeds were soaked in deionized water for 6 hours followed by soaking them in nano zinc solutions @ 1000 ppm for 6 hours, incubated for 12 hours and sown.Foliar spray of ZnONPs@ 500 ppm at panicle initiation and flowering stages were given to respective treatments. The rice variety ADT R 37 of 110 days duration was cultivated. The fertilizers were applied based on treatment levels following the recommended fertilizer schedule of 120:40:40 NPK kg ha^{-1} as urea, superphosphate and muriate of potash were applied as basal and the 50% N and K were applied at tillering and panicle initiation stages. Biometric observations *viz.,* growth attributes, yield attributes and yield data were recorded at harvest stage. The grain and straw samples were analyzed for zinc content by adopting standard procedures and zinc uptake was computed. The datacollected from the study weresubjected to ANOVA in accordance with the experimental design (SPD) using AGRES statistical package and CD values were calculated at 5%level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth attributes

DSR recorded the highest among the method of cultivation (103.6 cm), followed by TPR (101.4 cm) and AR (98.4 cm). Among the nutrient management, the highest plant height of 107.3 cm was observed with S_8- 75% RDF+ fortified *insitu* rice residue + ZnO NPs (SP +FS) irrespective of cultivation methods (Table 2). In nutrient management practices highest plant was recorded in *insitu* fortified rice residue compost + ZnO NPs (SP + FS),which might be due to fortification of FYM or rice residue with humic acid and seaweed extract (Kumar *et al.,* 2014). Application of nano zinc fertilizer improved the zinc use efficiency and thereby improved the growth parameters of rice over $ZnSO_4$ and control. The results corroborated with that of Singh *et al.*. (2019).

The number of tillers and LAI were recorded maximum with TPR -458 and 5.93, followed by DSR with 445 and 5.87and the lowest with AR-403 and 5.35, respectively (Table 2). Among the nutrient management, S_8 - fortified rice residue + ZnO NPs (SP+FS) recorded higher tillers of 507 and LAIof6.42 and it was comparable with same treatment with fortified FYM (S_7) with 495 tillers and LAI of 6.33. The lowest tillers and LAI were recorded in the control. The maximum tillers and LAIwere obtained with TPR and DSR, which might be due to the low weed occurrence. These results were agreed to the findings of Sahu *et al.*(2018). Zinc improved the metabolic process of the plant, which lead to higher absorption of zinc and other essential nutrients for the growth and resulted in superior rice growth and tiller numbers. The results were obtained are in accordance with Aminah *et al.* (2019).

Table 2: Effect of rice cultivation methods, fortified organic manures and nano zinc on growth and yield attributes of rice

Treatments	Plant height (cm)	No. of tillers/m^2	LAI	Panicle weight (g)	Test weight (g)	No. of filled grains / panicle	No. of productive tillers/m^2
Rice cultivation methods (M)							
M_1- TPR	101.4	458	5.93	3.88	23.3	136	384
M_2 - DSR	103.6	445	5.87	3.74	23.3	132	369
M_3 - AR	98.4	403	5.35	3.51	23.2	109	310
S. Ed	0.49	4.74	0.07	0.09	NS	1.70	5.66
C.D (LSD =0.05)	1.37	13.17	0.20	0.25	NS	4.73	15.72
Nutrient management (S)							
S_1- Control (100 % RDF)	93.5	359	4.91	3.41	22.8	103	290
S_2 - S_1+ $ZnSO_4$ SA @ 25 kg ha^{-1}	96.9	387	5.18	3.49	23.0	111	309
S_3 - 75 % RDF+ Fortified FYM + $ZnSO_4$ SA @ 25 kg ha^{-1}	99.0	407	5.51	3.60	23.1	120	329
S_4- 75 % RDF+ Fortified *insitu* rice residue + $ZnSO_4$ SA @ 25 kg ha^{-1}	100.6	424	5.56	3.67	23.2	123	344
S_5 - 75 % RDF+ Fortified FYM + ZnO NPs (SP)	101.7	444	5.86	3.74	23.3	129	366
S_6 - 75 % RDF+ Fortified *insitu* rice residue + ZnO NPs (SP)	103.9	460	5.96	3.82	23.4	132	376
S_7 - S_5 + ZnO NPs (FS)	106.0	495	6.33	3.94	23.5	141	406
S_8 - S_6 + ZnO NPs (FS)	107.3	507	6.42	4.01	23.6	147	417
S. Ed	1.48	10.37	0.09	0.08	NS	2.93	8.02
C.D (LSD =0.05)	2.98	20.94	0.17	0.15	NS	5.91	16.19
M at S interactions							
S. Ed	NS	NS	0.16	NS	NS	5.04	14.18
C.D (LSD =0.05)	NS	NS	0.34	NS	NS	10.61	30.33
S at M interactions							
S. Ed	NS	NS	0.15	NS	NS	5.07	13.89
C.D (LSD =0.05)	NS	NS	0.30	NS	NS	10.24	28.04

Yield attributes

TPR plots noticed a higher number of productive tillers (384) and it was comparable with DSR (369) and least with AR (310) (Table 2). Among the nutrient managements, the highest productive tillers were recorded with 75% RDF+ fortified rice residue compost + ZnO NPs(SP+FS) and lowest with control (100% RDF) with 417 and 290, respectively.TPR with 75% RDF+ fortified rice residue compost + ZnO NPs (SP+FS) recorded the highest productive tillers than other combinations (Ishfaq, 2020). Nano zinc application increased the Zn uptake by rice which played a significant role in metabolic, physiological and biochemical activities which aided in producing the higher number of productive tillers (Kheyri *et al.*., 2019).

The test weight ranged from 23.2 to 23.3 g invarious cultivation methods and 22.8 to 23.6 in nutrient management practices (Table 2). This could probably due to the genetic character of the variety. TPR recorded a higher panicle weight and number of filler grains with 3.88 g and 136, followed by DSR - 3.74 g and 132 and lowest with AR -3.51 g and 109, respectively. The highest and the lowest panicle weight and number of filled grains were recorded with S_8 - fortified rice residue + ZnO NPs (SP+FS) - 4.01 g and 147 and control- 3.41 g and 103, respectively. The finding corroborates with the results of Jusoh *et al.* (2013).

Table 3: Effect of rice cultivation methods, fortified organic manures and nano zinc on yield, zinc content and uptake of rice

Treatments	Grain yield t ha^{-1}	Straw yield t ha^{-1}	Grain		Straw	
			Zn Content (mg kg^{-1})	Zn Uptake (g ha^{-1})	Zn Content (mg kg^{-1})	Zn Uptake (g ha^{-1})
Rice cultivation methods (M)						
M_1- TPR	5.62	7.16	27.42	157.1	36.31	264.3
M_2 - DSR	5.44	6.96	26.86	149.0	35.12	249.0
M_3 - AR	4.64	5.76	23.67	111.0	32.14	186.8
S. Ed	0.10	0.08	0.38	3.01	0.63	4.93
C.D (LSD =0.05)	0.27	0.22	1.05	8.36	1.76	13.69
Nutrient management (S)						
S_1- Control (100 % RDF)	4.29	5.49	19.12	82.2	26.93	148.5
S_2 - S_1+ $ZnSO_4$ SA @ 25 kg ha^{-1}	4.67	5.75	21.44	100.4	29.23	168.5
S_3 - 75 % RDF+ Fortified FYM + $ZnSO_4$ SA @ 25 kg ha^{-1}	4.93	6.21	24.52	121.3	32.42	202.0
S_4 - 75 % RDF+ Fortified *insitu* rice residue + $ZnSO_4$ SA @ 25 kg ha^{-1}	5.11	6.46	25.32	129.9	34.22	221.6
S_5 - 75 % RDF+ Fortified FYM + ZnO NPs (SP)	5.31	6.71	27.12	144.7	35.68	240.0
S_6 - 75 % RDF+ Fortified *insitu* rice residue + ZnO NPs (SP)	5.51	6.97	27.86	154.0	36.51	255.0
S_7 - S_5 + ZnO NPs (FS)	5.96	7.61	30.90	186.0	40.18	308.7
S_8 - S_6 + ZnO NPs (FS)	6.08	7.79	31.59	193.8	41.00	322.9
S. Ed	0.10	0.13	0.63	4.25	0.93	7.48
C.D (LSD =0.05)	0.20	0.26	1.28	8.58	1.88	15.09
M at S interactions						
S. Ed	0.19	0.23	1.09	7.52	1.63	13.08
C.D (LSD =0.05)	0.42	0.48	2.31	16.09	3.49	27.81
S at M interactions						
S. Ed	0.17	0.23	1.10	7.36	1.61	12.95
C.D (LSD =0.05)	0.35	0.46	2.22	14.86	3.26	26.14

Grain and straw yield

TPR recorded significantly higher grain and straw yield of 5.62and 7.16 t ha^{-1}, respectively and it was superior over AR (grain yield - 4.64 t ha^{-1} and straw yield -5.76 t ha^{-1}) and comparable with DSR (grain yield – 5.44 t ha^{-1} and straw yield – 6.96 t ha^{-1}). The grain yield increase in TPR was 3.45 and 21.24% over DSR and AR, respectively. Among the nutrient managements, the highest grain and straw yield of 6.08 and 7.79t ha^{-1} was recorded with S_8-75% RDF+ *insitu* rice residue fortified with PGPM, humic acid and seaweed extract + ZnO NPs (SP+FS)irrespective of cultivation methods. The S_1 - control recorded the lowest grain and straw yield of 4.29 and 5.49t ha^{-1}. The significantly higher grain and straw yield were noticed with fortified rice residue/FYM + ZnO NPs (SP+FS) under TPR and DSR (Liu *et al.*, 2015). Fortification of rice residue with PGPM and Bio Active compounds resulted in increased nutrient availability, the efficiency of fertilizers led to higher plant growth and yield attributes and thus resulted in higher yield of rice. These findings acknowledged with results obtained by Simarmata *et al.* (2016).Application of ZnO NPs improved the yield in rice over the control and $ZnSO_4$ application which maybe because of the delivery of Zn nutrient through ZnO NPs in the right dose and right size aided in enhancing the growth and yield attributes of rice crop. Similar findings were reported by Kheyri *et al.*(2019).

Zinc content and uptake

The TPR recorded significantly higher grain and straw Zn content of 27.42, 36.31 mg kg^{-1} and Zn uptake of 157.1 and 264.3 g ha^{-1}, respectively (Table 3). The lowest Zn content and uptake were recorded in AR 23.67 mg kg^{-1} and 111.0 g ha^{-1} (grain) and 32.14 mg kg^{-1} and 186.8 g ha^{-1} (straw). Among the nutrient management, fortified rice residue plus zinc supplement through nano particles as SP and FS observed higher grain and straw Zn content and uptake 31.59 and 41.00 mg kg^{-1} and 193.8 and 322.9 g ha^{-1}, respectively Among the interactions, TPR and DSR with fortified rice residue or FYM + ZnO NPs recorded significantly higher Zn content and uptake. Since the diameter of ZnO NPs diameter less than the stomatal pore size can penetrate and move inside plant tissues may be attributed to the increased zinc transport and deposition. Thus, these findings emphasize the role of ZnO NPs in remediation of Zn deficiency and improvement in the yield and Zn content in rice as reported by Bala *et al.* (2019).

From this study, it can be concluded that TPR showed its superiority among the establishment methods, *in situ* incorporation of fortified rice residues compost and nano zinc application as seed priming and foliar spray significantly increased the growth and yield of rice and saves inorganic fertilizers considerably. Thus, PGPM, humic acid and seaweed extract fortified organic manures either FYM or rice residue compost, nano zinc as seed priming and foliar spray under TPR or DSR have the potential to maximize rice production without foregoing soil sustainability.

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